Pulse Amplitude Modulation (PAM)

If ***w(t)*** is an analog waveform bandlimited to ***B*** hertz, the PAM signal that uses natural sampling is

$$V_{PAM}(t) = W_s(t) = w(t)\, s(t)$$

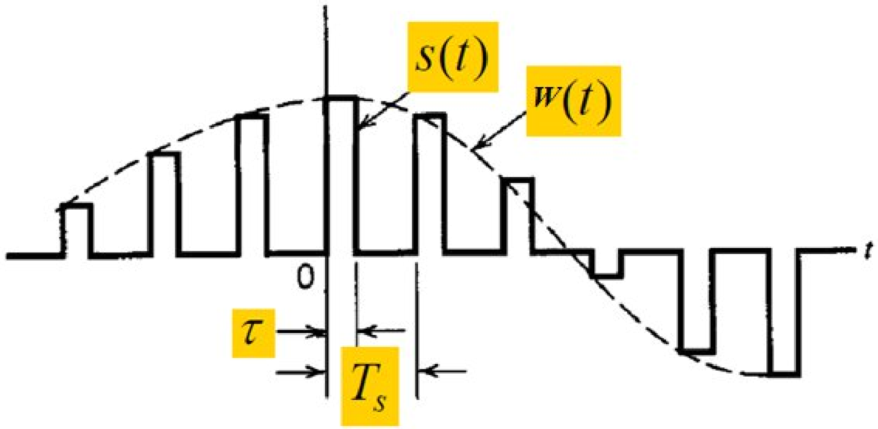
$$s(t) = \sum_{-\infty}^{\infty} \Pi\left(\frac{t - k\,Ts}{\tau}\right)$$

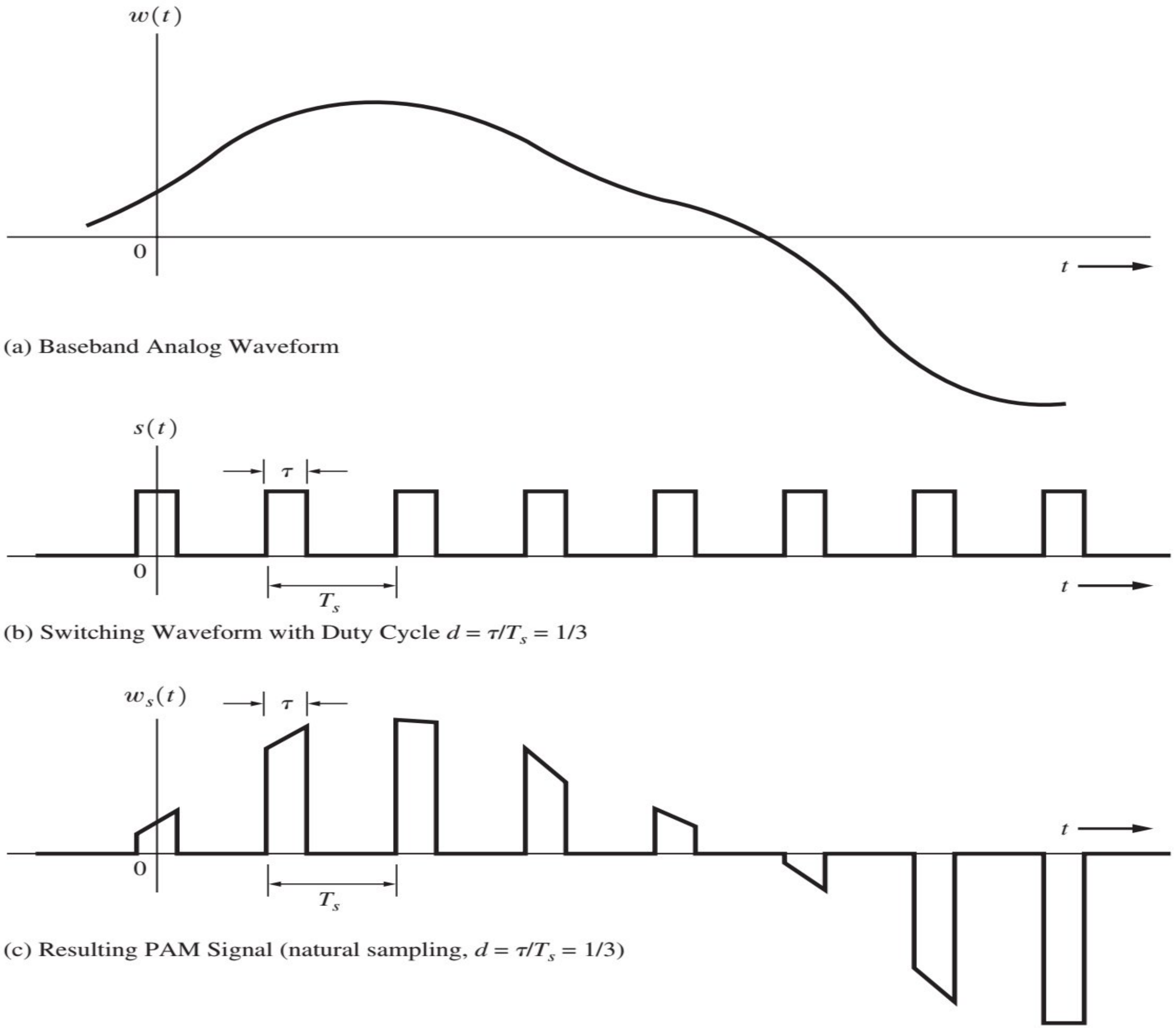
s(t) is a rectangular switching waveform

fs = 1/*Ts* ≥ 2*B*.

The duty cycle (***D***) is defined as the ratio between the pulse duration, or pulse width (τ) and the period (T_s) of a rectangular waveform:-

$$D = \frac{\tau}{T_s}$$





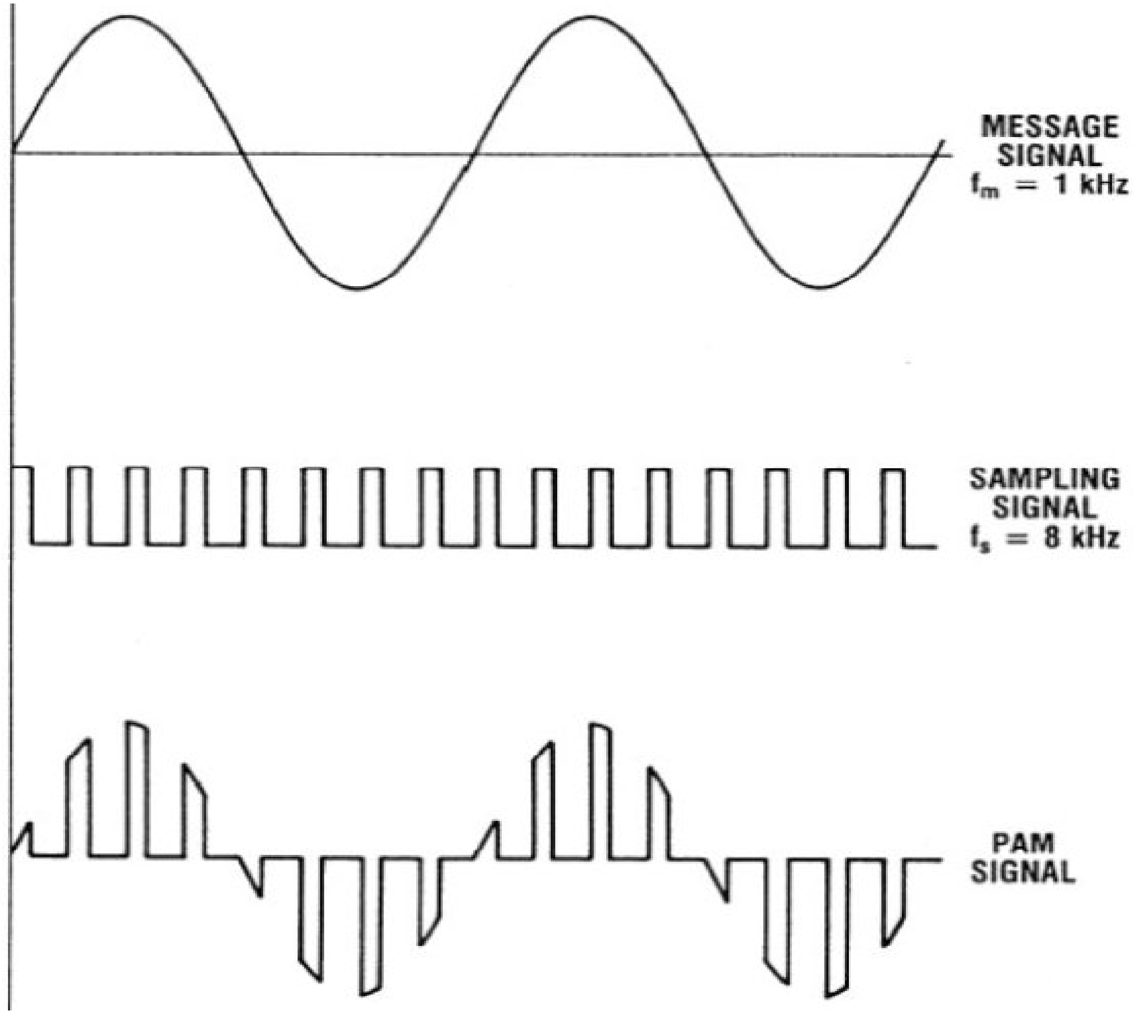
(a) Baseband Analog Waveform

(b) Switching Waveform with Duty Cycle $d = \tau/T_s = 1/3$

(c) Resulting PAM Signal (natural sampling, $d = \tau/T_s = 1/3$)

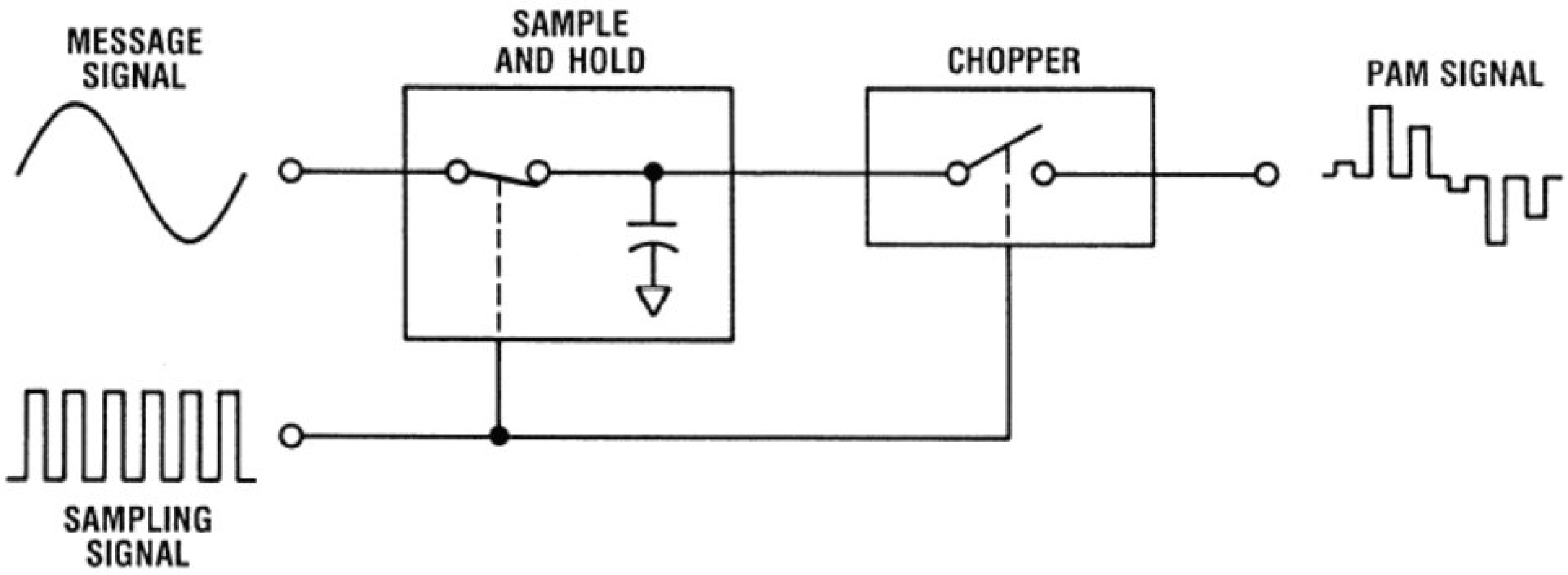
Example Plot the PAM signal when the message signal is a sinusoidal with a frequency of 1KHz and the carrier signal is pulse with frequency of 8 KHz. Consider the sampling used here is natural sampling.

Solution



Generation of PAM

The second type of PAM uses the flat-top sampling, a sample-and-hold circuit is used in conjunction with the chopper to hold the amplitude of each pulse at a constant level during the sampling time



Flat-top sampling – generation of PAM signals.

A **rectangular** sampling **signal** is used and signal sample has non-zero length according to for example the higher level of rectangular signal. Only the initial value of continuous signal amplitude is sampled (sample and hold circuit is used), so that sample is flat-top.

Sample & Hold Circuit

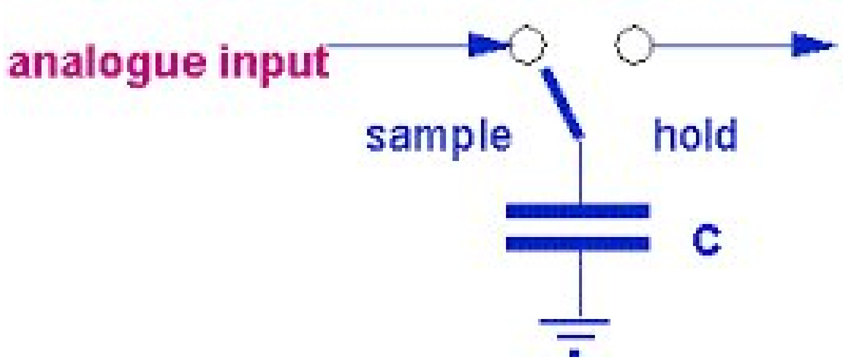
The purpose of this circuit is to hold the analogue value steady for a short time while the converter or other following system performs some operation that takes a little time.

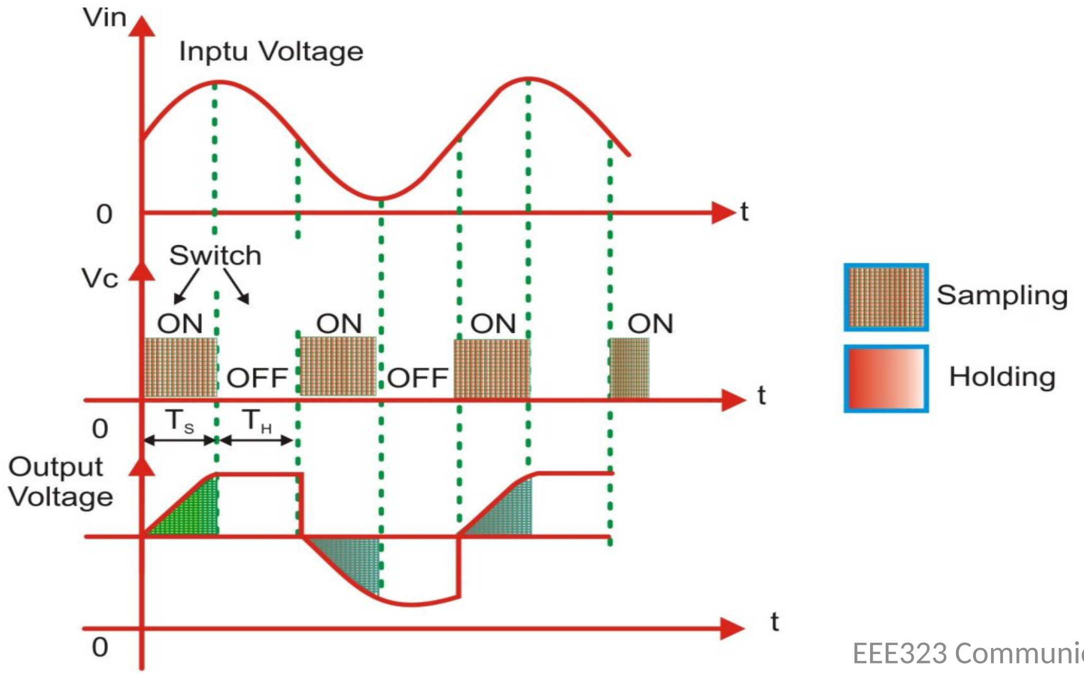
Sampling mode:

In this mode, the switch is in the closed position and the capacitor charges to the instantaneous input voltage.

Hold mode:

In this mode, the switch is in the open position. The capacitor is now disconnected from the input. As there is no path for the capacitor to discharge, it will hold the voltage on it just before opening the switch. The capacitor will hold this voltage till the next sampling instant.

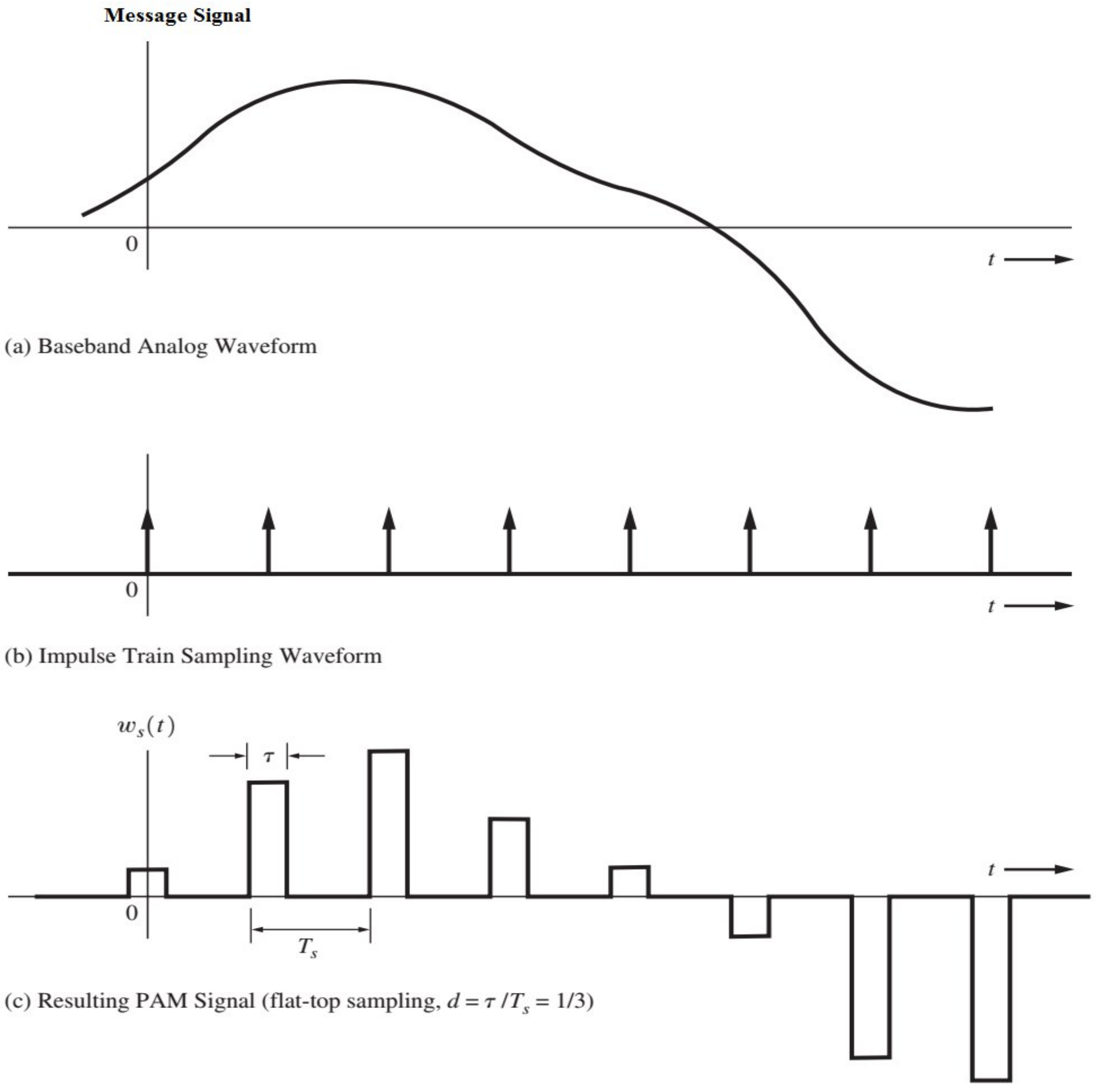




Sample and hold wave form

Example Plot the PAM signal when the message signal shown below while the carrier signal is impulse train. Consider the sampling used here is flat-top sampling.

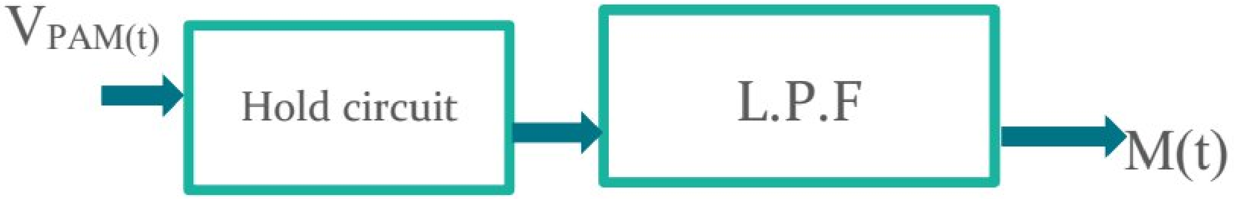
Solution



PAM signal with flat-top sampling.

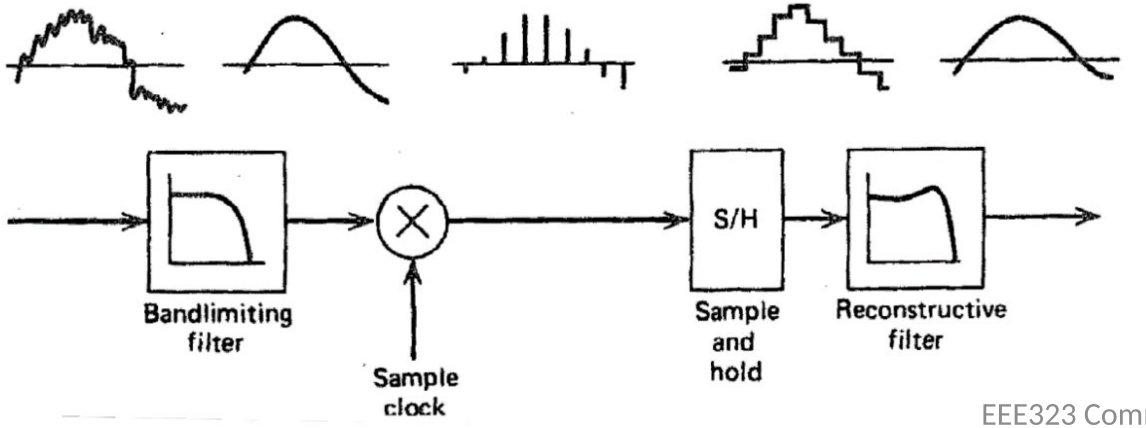
PAM Demodulation

Demodulation of PAM signal, PAM is fed to the low pass filter (LPF) . The hold circuit holds the signal peak amplitudes (i.e by using capacitor the peak values are hold and is given to a LPF. The LPF eliminates high frequency ripples and generates the demodulated signal which as its amplitude proportional to PAM signal at all time instant. This signal is then applied to an inverting amplifier to amplify its signal level to have the demodulated output with almost equal amplitude with the modulating signal.



In PAM, **Bandwidth is very large** as compared to modulating signal frequency. In PAM, the amplitude of the rectangular pulse train is varied according to the instantaneous value of the modulating signal. Due to this, **the required power for transmission is also varied**. Due to varying amplitude of carrier, the interference of **noise is very high in PAM**. So it is difficult to remove noise at receiver.

End-to-End PAM system



Pulse Time modulation (PTM)

In Pulse time modulation (PTM), **amplitude** of the carrier is kept constant and the **Position or width** of the carrier varies with the amplitude of the modulating signal at the time of sampling. Pulse width modulation and pulse position modulation are the types of Pulse Time Modulation. As there is no variation in the amplitude of the carrier, the noise may be easily removed at the receiver.

In PTM, the timing of the pulses of the carrier is varied in accordance with modulating signal. Types of PTM are

1- Pulse Width Modulation (PWM)

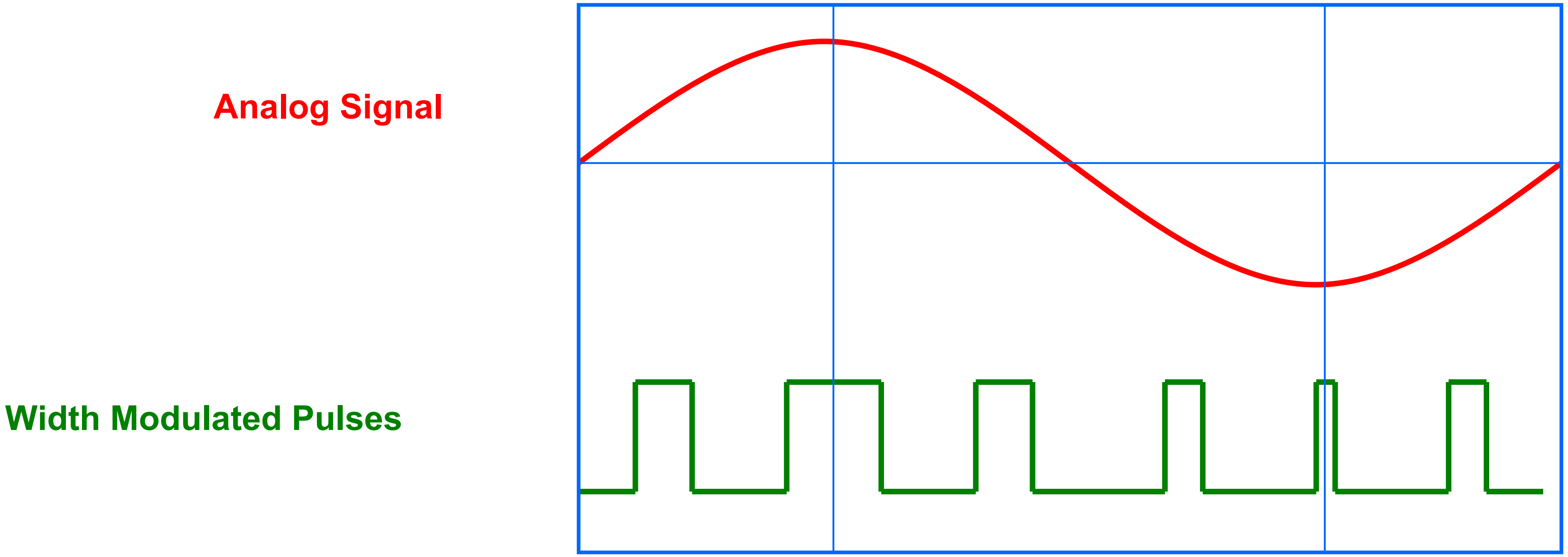
2- pulse Position Modulation (PPM)

In PWM, the width of the carrier varies with the amplitude of the modulating signal at the time of sampling. Pulse width modulation is a type of Pulse Time Modulation. As there is no variation in the amplitude of the carrier, the noise may be easily removed at the receiver. **It does not require synchronization between the transmitter and the receiver.**

In PPM, the position of the pulse of the carrier is varied with reference to the position of a reference pulse. The position is varied in accordance with the sampled modulating signal. **In PPM, synchronization is required between the transmitter and the receiver.** Large bandwidth is required in Pulse position Modulation as compared to the Pulse amplitude modulation.

Pulse Width Modulation (PWM or PLM or PDM):

In this type, the amplitude is maintained constant but the **duration or length or width** of each pulse is varied in accordance with instantaneous value of the analog signal. The negative side of the signal is brought to the positive side by adding a fixed DC voltage.

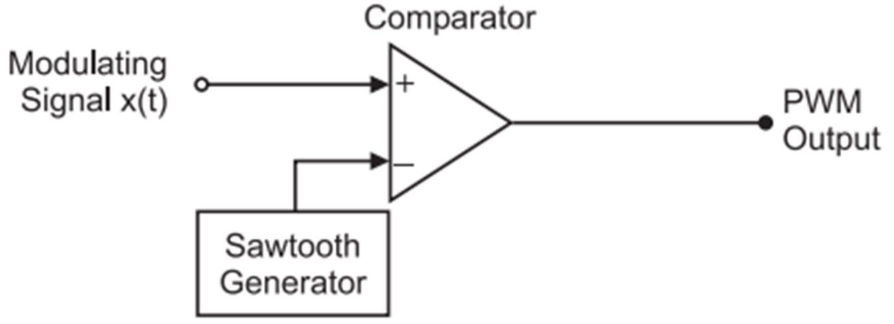


As we can observe, the amplitude and the frequency of the PWM wave remain constant. Only the width changes. That is why the information is contained in the width variation. This is similar to FM. As the noise is normally additive noise, it changes the amplitude of the PWM signal.

At the receiver, it is possible to remove these unwanted amplitude variations very easily by means of a limiter circuits. As the information is contained in the width variation, it is unaffected by the amplitude variations introduced by the noise. Thus, the PWM system is more immune to noise than the PAM signal.

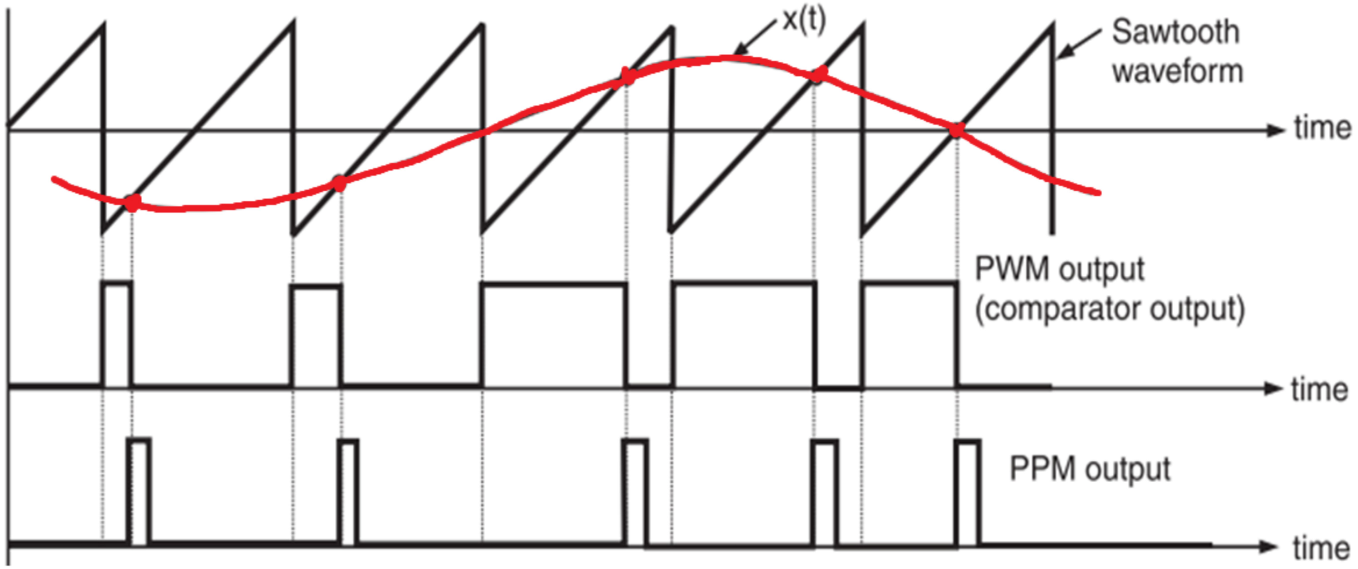
Generation of PWM Signal

The block diagram of a PWM signal generator is shown in fig below. This circuit can also be used for the generation of PPM signal.



PWM and PPM Generator

- A sawtooth generator generates a sawtooth signal of frequency f_s, and this sawtooth signal in this case is used as a sampling signal.
- It is applied to the inverting terminal of a comparator.
- The **modulating signal x (t)** is applied to the non-inverting terminal of the same comparator.
- The comparator output will remain high as long as the instantaneous amplitude of x (t) is higher than that of the ramp signal.
- This gives rise to a PWM signal at the comparator output as shown in fig.



Detection of PWM Signal

The circuit for the detection of PWM signal is shown in fig. below. It works as:

- The PWM signal received at the input of the detection circuit is contaminated with noise. This signal is applied to pulse generator circuit which regenerates the PWM signal. Thus, some of the noise is removed and the pulses are squared up.
- The regenerated pulses are applied to a reference pulse generator. It produces a train of constant amplitude, constant width pulses.
- These pulses are synchronized to the leading edges of the regenerated PWM pulses but delayed by a fixed interval.
- The regenerated PWM pulses are also applied to a ramp generator. At the output of it, we get a constant slope ramp for the duration of the pulse. The height of the ramp is thus proportional to the width of the PWM pulses.
- At the end of the pulse, a sample and hold amplifier retains the final ramp voltage until it is reset at the end of the pulse.
- The constant amplitude pulses at the output of reference pulse generator are then added to the ramp signal.
- The output of the adder is then clipped off at a threshold level to generate a PAM signal at the output of the clipper.
- A low pass filter is used to recover the original modulating signal back from the PAM signal. The waveforms for this circuit have been shown